Attachment 4
The Uinta Basin

The Uinta Coal Basin is located mostly within eastern Utah; a very small portion of the basin is in northwestern Colorado (Figure A4-1). The basin covers approximately 14,450 square miles (Quarterly Review, 1993) and is structurally separated from the Piceance Basin by the Douglas Creek Arch (Figure A4-1), an up-warp near the Utah – Colorado state line. Coalbeds are present within Cretaceous strata throughout much of the Uinta Basin. However, coalbed methane exploration, to date, has targeted coalbeds in the Ferron Sandstone Member of the Mancos Shale and coalbeds in the Blackhawk Formation of the Mesaverde Group. The total, in-place, coalbed gas resources in the Wasatch Plateau, Emory, Book Cliffs and Sago coal fields have been estimated at 8 trillion cubic feet (Tcf) to more than 10 Tcf by the Utah Geological Survey (Gloyn and Sommer, 1993). This estimate is based on extrapolation of known coal resources to a depth of 9,000 feet and an average projected gas content of 330 cubic feet per ton and does not include the Tabby Mountain or Vernal coalfields, or the Sevier-Sanpete coal region. Total production stood at 75.7 billion cubic feet (Bcf) of coalbed methane in 2000 (GTI, 2002).

4.1 Basin Geology

Much of the Rocky Mountain region, including the Uinta Basin was covered by an epicontinental sea. Deposition in the sea lasted from the Albian (about 100 million years ago) through the Cenonmanian (about 83 million years ago), with the deposition of the upper part of the Mesaverde Group generally marking the end of marine deposition in the basin (Howells et al., 1987).

The Uinta Basin formed as a result of uplift and deformation that began in the Late Cretaceous. The Cretaceous sediments outcrop along the perimeter of the basin. The basin is asymmetrical in shape with strata on the northern flank of the basin dipping steeply toward the basin axis, while strata on the southern flank dip gently toward the basin axis. The stratigraphic units of the coal bearing Cretaceous rocks of the Uinta Basin are shown in Figure A4-2.

Two Cretaceous stratigraphic units have been targeted for coalbed methane exploration: the Ferron Sandstone Member of the Mancos Shale and the Blackhawk Formation of the Mesaverde Group (Figure A4-2). The Ferron Sandstone Member was deposited in the Last Chance delta, a fluvial-deltaic environment (Garrison et al., 1997). The coalbeds and interbedded sandstone units form a wedge of clastic sediment 150 to 750 feet thick stratigraphically above the Tunuck Shale Member of the Mancos Shale and below the Lower Blue Gate Shale Member of the Mancos Shale (Figure A4-2). Both of these shale units have a very low permeability and constitute confining units for water and gas in the Ferron Sandstone Member. The coal-bearing rocks are thickest to the west and south margins of the basin, nearer to the upland sources of sediment. Coalmines producing from the Ferron Sandstone Member are located along the eastern boundary of the Wasatch Plateau south of Castle Dale, Utah (Figure A4-1). Depths to coal in the Ferron Sandstone Member range from 1,000 to over 7,000 feet (Garrison et al., 1997). Primary coalbed methane activity from the Ferron Sandstone takes place in the Drunkard's Wash Unit. Total coal thickness in this area ranges from 4 to 48 feet (averaging 24 feet) from depths of 1,200 to 3,400 feet (Lamarre and Burns, 1996).

The Blackhawk Formation consists of coal interbedded with sandstone and a combination of shale and siltstone. The Blackhawk Formation is underlain by the Star Point Sandstone and overlain by the Castlegate Sandstone (Figure A4-2). The Castlegate Project in the Book Cliffs coalfield initially targeted coals in the Blackhawk Formation at depths ranging from 4,200 to 4,400 feet (Gloyn and Sommer, 1993).

4.2 Basin Hydrology and USDW Identification

Groundwater hydrology of the Uinta Basin is controlled primarily by the geologic structure of the region (Howells et al., 1987). Variations of aquifer and aquitard permeability owing to differences of lithology and facies changes also play an important role in the hydrology, as does widespread faulting and fracturing of the rocks (Howells et al., 1987). Because of the basin's structure, the area may be a groundwater basin with internal drainage. If there were a deep groundwater outlet for the basin, it would be along or near the axis of the Uinta Basin at its western edge. The general pattern of groundwater flow is centripetal, with water flowing inward from recharge areas at exposures of permeable strata at the margins of the basin. Recharge is greatest near the northern edge of the basin. Other recharge areas include Eocene and Oligocene Formations in the basin interior.

Most of the sandstone formations in the Mesozoic rocks in the Upper Colorado River Basin are identified as aquifers by the United States Geological Survey (Freethey and Cordy, 1991). Freethey and Cordy stated that in the Uinta Basin, the older and deeper aquifers in strata below the Ferron Sandstone Member, (for example, the Navajo-Nugget Aquifer, Entrada-Preuss Aquifer, Morrison Aquifer, and the Dakota Aquifer) generally contain very saline to briny water, with total dissolved solids (TDS) values greater than 10,000 milligrams per liter (mg/L). The water quality component of the underground source of drinking water (USDW) definition specifies that a USDW contain less than 10,000 mg/L of TDS. The Ferron Sandstone Member (Figure A4-3) is designated as a producing aquifer in east-central Utah (Freethey and Cordy, 1991). In regard to the Mesaverde Group Aquifer, which includes the Star Point Sandstone, the Blackhawk Formation, the Castlegate Sandstone and the Price River Formation, (Figure A4-3) Freethey and Cordy (1991), stated that, "water in these aquifers is more likely to be developed where the saturated thickness is large and the depth to the aquifer is less than 2,000 ft." They further stated that the margins of the Uinta Basin where these rocks are near the surface or outcrop is a possible location for development of groundwater with low enough TDS to be used for drinking water.

Wells in the Ferron Sandstone Member at the Drunkard's Wash coalbed methane field typically penetrate to depths ranging from 1,200 to 3,400 feet (Lamarre and Burns, 1996). An average water quality value of 13,120 mg/L TDS (Gwynn, 1998) for production waters that have been retained in catchment ponds suggests that these wells are not within a USDW. Gwynn (1998) however, does state that due to the ponding of the produced water in evaporation lagoons, the concentration of salts in these waters has probably increased from their original levels. This implies that these water quality data may not be useful in the confirmation of USDW qualifications. Quarterly Review (1993) reported that three wells producing gas and water from the Ferron Sandstone Member coalbeds in the Drunkard's Wash field yielded over 49,000 gallons of water per day with a TDS level of about 5,000 mg/L (sodium bicarbonate) during the first 2 to 3 months of operation. The Ferron Sandstone is hydrologically confined above and below by shale members of the Mancos Shale formation. Water produced from the Ferron Sandstone is thought to be connate water that was trapped in the sediment during coalification (Gloyn and Sommer, 1993). Hunt (Utah Division of Oil, Gas, and Mining, 2001) noted that there were no USDWs located immediately above the Ferron Sandstone Member due to the thick tongues of Mancos Shale that encapsulate the coal-bearing interval (Figure A4-2).

Beds targeted for methane gas exploration and production within the Blackhawk Formation are approximately 4,200 to 4,400 feet below the ground surface (Gloyn and Sommer, 1993). Coalbed gas production in the Castlegate Field accounted for less than 10 percent of the coalbed methane production in the Uinta Basin (Petzet, 1996). The average gas well producing from the coalbeds in the Blackhawk Formation (Castlegate field) yielded 318 barrels of water per day, and TDS levels of 5,489 mg/L have been measured in the produced waters (Gloyn and Sommer, 1993).

According to the State of Utah Department of Natural Resources (DNR), Division of Oil, Gas and Mining, the water quality in the Ferron and Blackhawk varies greatly with location, each having some TDS levels below and some above 10,000 mg/L (Utah DNR, 2002). In general, the quality of Blackhawk water is higher than that of Ferron water. The most recent Underground Injection Control application received for the Drunkard's Wash field (Ferron) showed a composite quality of input water to be about 31,000 mg/L TDS, and for the Castlegate field (Blackhawk) 9,286 mg/L TDS. At some locations, either formation member would not qualify as a USDW.

In the western part of the Uinta Basin, the Castlegate Sandstone, an aquifer, is separated from the Black Hawk Formation coalbeds by approximately 300 feet of alternating shale and sandstone (Utah DNR 2002). The Star Point Sandstone is located below approximately 400 feet of alternating sandstone and shale that underlies the bottom coal of the Black Hawk Formation. In some areas, the shale and sandstone underlying the Black Hawk coals are highly faulted. There is some potential that hydraulic fracturing fluids could be transported through natural fracture networks in these areas and reach the Star Point Sandstone. The relatively impermeable upper Blue Gate Shale Member of the Mancos Shale Further would prevent further downward migration.

In reference to the quality of water produced by the coalbed gas wells in both the Ferron Sandstone Member of the Mancos Shale and the Blackhawk Formation, Quarterly Review (1993) states: "Disposal of produced water does not appear to present a major environmental problem in the Uinta basin, unlike the San Juan and some other western basins. Rates are moderate, 200 to 300 barrels per day per well during early stages of production and TDS levels are not high (about 5,000 mg/L)." Because these TDS values are less than the 10,000 mg/L limit, both the Ferron Sandstone Member of the Mancos Shale and the Blackhawk Formation may qualify as USDWs.

Tabet (2001) suggests that coalbed methane extraction wells are not located in "producing" aquifers and that most of the potable water in the sparsely populated area is supplied by surface water and shallow alluvial aquifers.

4.3 Coalbed Methane Production Activity

Full-scale exploration in the Uinta Basin began in the 1990s (Quarterly Review, 1993). The most active operators at that time were PG&E Resources Company, the River Gas Corporation, Cockrell Oil Corporation, and Anadarko Petroleum Corporation. PG&E acquired the Castlegate Field, from Cockrell Oil (Gloyn and Sommer, 1993). Gas was produced from coalbeds in the Blackhawk Formation. The five wells initially drilled in the Castlegate Field were hydraulically fractured with 80,000 to 143,000 pounds of sand and unreported volumes of fluid. Other wells were to be fractured with a low-residue gel system to ensure breakdown within the reservoir (Quarterly Review, 1993).

The Castlegate field was off-line due to production water disposal problems (Tabet, 2001; and Hunt, Utah Division of Oil, Gas, and Mining, 2001). According, to the State of Utah DNR, Division of Oil, Gas and Mining, the field is now on production (Utah DNR, 2002).

The River Gas Corporation operates the Drunkard's Wash Unit, producing methane gas from coals within the Ferron Sandstone Member. The company reported that high fracture gradients hampered hydraulic fracturing stimulations using cross-linked borate gel with 250,000 pounds of proppant (Quarterly Review, 1993). Excessive proppant flowback resulted in one well where nitrogen foam was used for the fracturing. The Buzzard Bench Field, also producing gas from the Ferron Sandstone Member, was initially operated by Chandler & Associates, Inc. (Petzet, 1996) and is currently being managed by Texaco (Garrison et al., 1997).

A query of a database covering the Uinta Basin revealed that there are about 1,255 coalbed methane wells in production in the basin (Osborne, 2002). Gas Technology Institute (GTI) places the annual coalbed methane production in the Uinta Basin at 75.7 Bcf in 2000 (GTI, 2002).

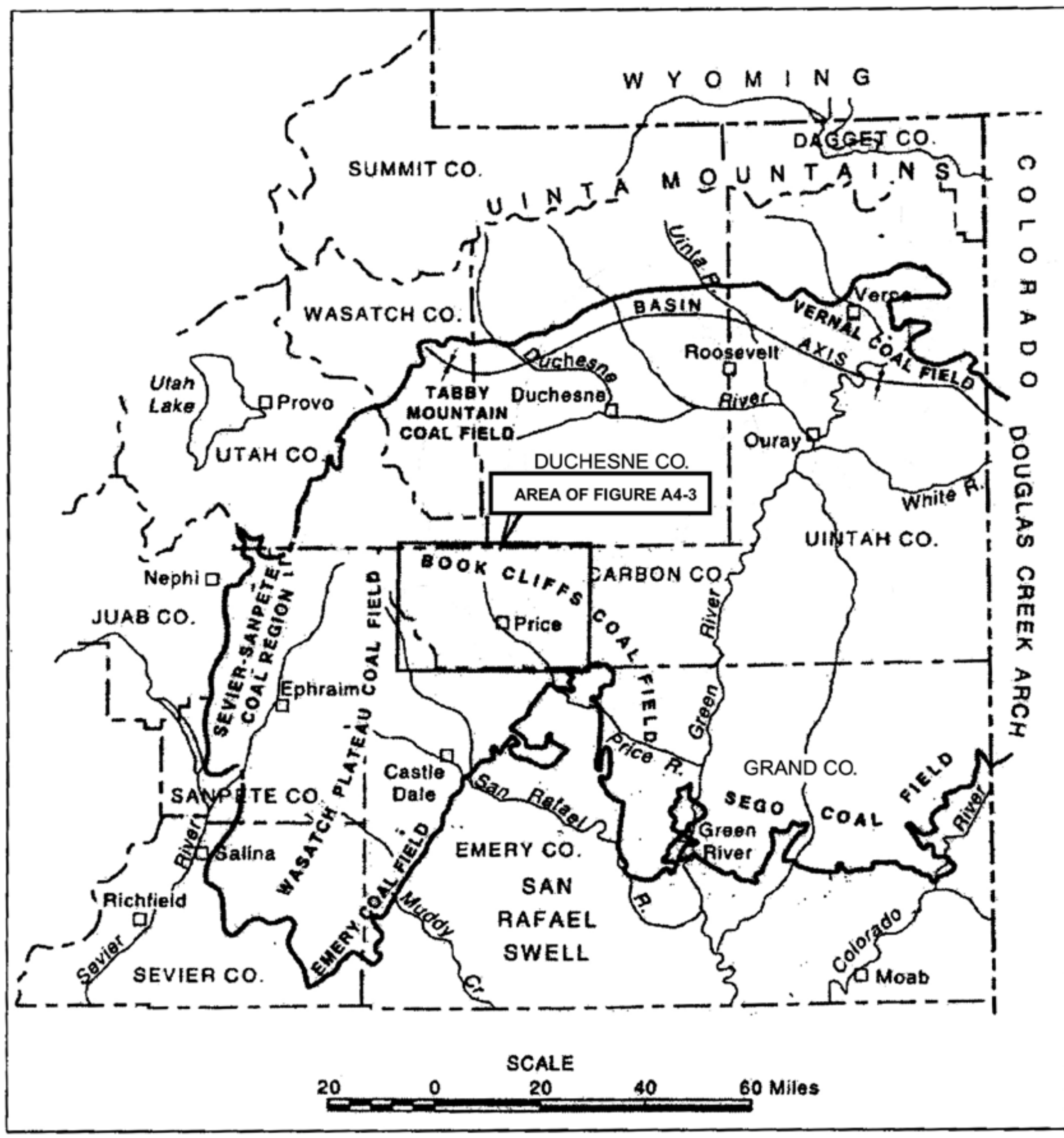
4.4 Summary

Waters from coalbed methane production in the Ferron Sandstone Member of the Mancos Shale in the Drunkard's Wash Unit are conflictingly reported to have TDS values of about 13,000 mg/L according to one source of information or to have levels of TDS of about 5,000 mg/L from another. However, the higher values were derived from water samples taken from evaporation lagoons and these high values might represent elevated concentrations of salts owing to evaporation. Consequently, if the more moderate TDS levels were correct, then the Ferron Sandstone would qualify as a USDW.

According to the State of Utah DNR, Division of Oil, Gas and Mining, the water quality in the Ferron and Blackhawk varies greatly with location, each having TDS levels below and above 10,000 mg/L (Utah DNR, 2002). In general, the quality of Blackhawk water is fresher than Ferron water. The most recent Underground Injection Control application received for the Drunkard's Wash field (Ferron) showed a composite quality of input water to be about 31,000 mg/L TDS, and for the Castlegate field (Blackhawk) 9,286 mg/L TDS. At some locations, neither formation member would qualify as a USDW.

The Drunkard's Wash and Castlegate coalbed methane extraction fields are located in a sparsely populated section of Utah. Tabet (Utah Geological Survey, 2001) suggests that coalbed gas extraction wells are not located in "producing" aquifers and that most of the potable water in the sparsely populated area is supplied by surface water and shallow alluvial aquifers.

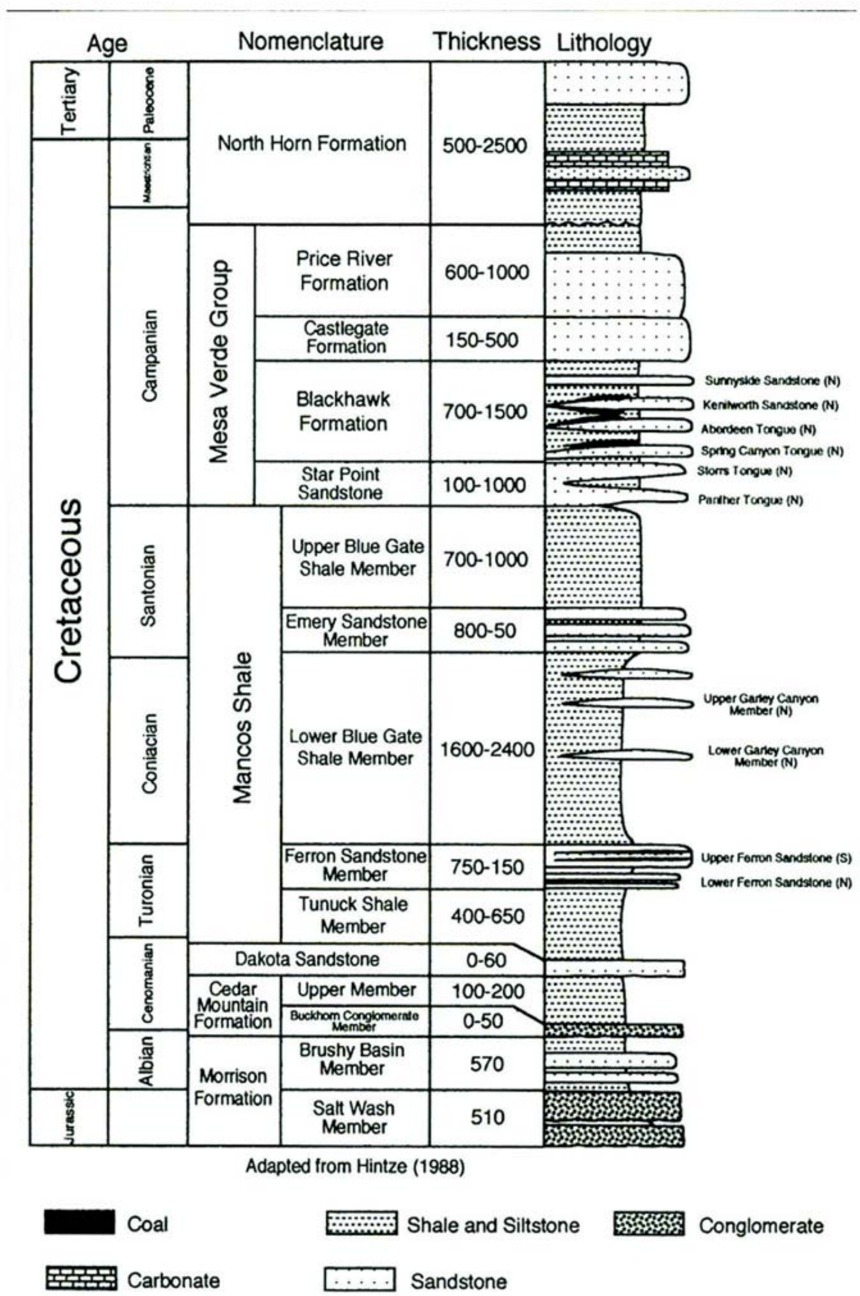
The Blackhawk Formation is underlain by 300 feet of shale and sandstone that separate it from the Castlegate Sandstone aquifer. It is underlain by similar geologic strata, which separate it for the Star Point Sandstone. Only in highly faulted areas is there a reasonable possibility that hydraulic fracturing fluids could migrate down to the Star Point Sandstone.



Index Map of Coal Fields in Uinta Basin, Utah (Quarterly Review, 1993)

7/14/01 kk 1027-HF-Uinta-1.cdr

Figure A4-1



Stratigraphic Column for the Cretaceous of the Castle Valley (Garrison et al., 1997)

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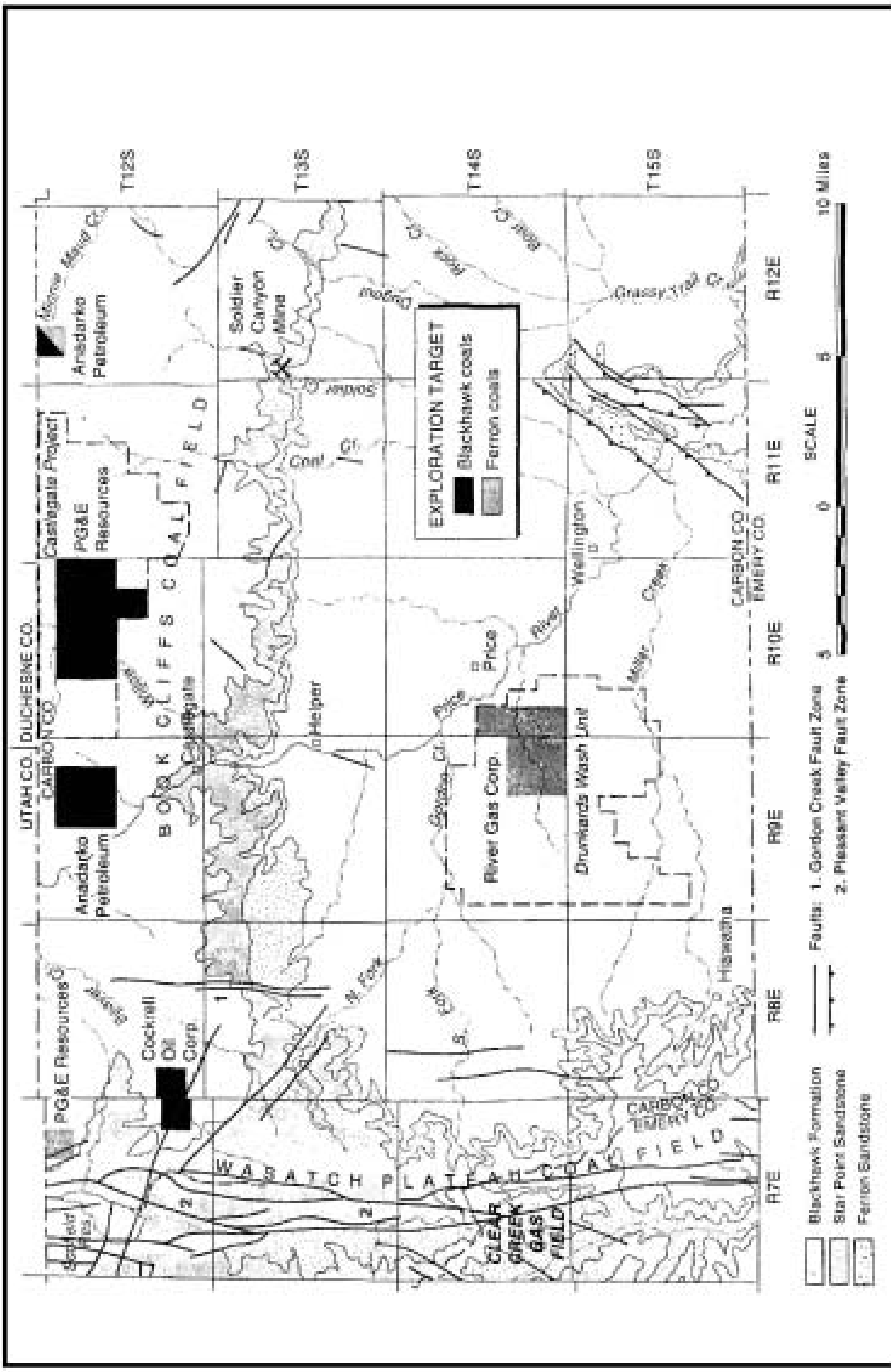
Figure A4-2



Coalbed Methane Development in Carbon County, Utah. (Methane from Coal Seams Technology, 1993)
Areas shown may not represent actual field, unit, or lease boundaries.

Figure A4-3

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